932001

Admin. Record

Design-Build Work Plan for the Airco Parcel, Niagara Falls, New York

Prepared for

The BOC Group
100 Mountain Avenue
Murray Hill, New Jersey 07974

Prepared by

EA Engineering, P.C. and Its Affiliate
EA Science and Technology
3 Washington Center
Newburgh, New York 12550
(845) 565-8100

April 2003
Revision: 0
Project No. 12040.83

Design-Build Work Plan
for the
Airco Parcel, Niagara Falls, New York

Prepared for

The BOC Group
100 Mountain Avenue
Murray Hill, New Jersey 07974

Prepared by

EA Engineering, P.C. and Its Affiliate
EA Science and Technology
3 Washington Center
Newburgh, New York

4-15-03
Date

David S. Santoro, P.E., L.S., President
EA Engineering, P.C.

4-15-03
Date

Charles E. McLeod, Jr., P.E., Project Manager/Vice President
EA Engineering, P.C.

April 2003
Revision: 0
Project No. 12040.83

Design-Build Work Plan
for the
Airco Parcel, Niagara Falls, New York

Prepared for

The BOC Group
100 Mountain Avenue
Murray Hill, New Jersey 07974

Prepared by

EA Engineering, P.C. and Its Affiliate
EA Science and Technology
3 Washington Center
Newburgh, New York

4-15-03

David S. Santoro, P.E., L.S., President — Date
EA Engineering, P.C.

4-15-03

Charles E. McLeod, Jr., P.E., Project Manager/Vice President — Date
EA Engineering, P.C.

April 2003
Revision: 0
Project No. 12040.83

From: <cem@eaest.com>
To: "Michael Hinton" <mjhinton@gw.dec.state.ny.us>
Date: 3/26/04 1:52PM
Subject: Airco Parcel mosquito control

Mike -

Mike, as discussed on the phone, EA would like to pursue stocking the engineered wetland with a minnow species that consume invertebrate larvae, instead of chemical applications . This is a fairly common practice--there are several species that consume considerable quantities of mosquito larvae--it is cleaner, safer and cheaper in the long run. We would consider using a species of Fundulus or Gambusia. When you speak to the fish and wildlife folks, can you mention it to them and get there feedback?

Also, we will be finalizing the Post-Closure Plan, including the O&M manual next week, so feedback as to the desired frequency of identification would be helpful. I am thinking twice during the summer. Once in July, and once in September. Let me know your thoughts.

If approved, we would likely stock the pond in late July early August.

Thanks -

Chip

Charles E. McLeod, Jr., P.E.
EA Engineering P.C. and its affiliate
EA Science and Technology
3 Washington Center
Newburgh, New York 12550
(845) 565-8100
Extension No. 1008

CC: <mike.resh@boc.com>

EA Engineering, P.C.
EA Science and Technology

The Maple Building
3 Washington Center
Newburgh, NY 12550
Telephone: 845-565-8100
Fax: 845-565-8203
www.eaest.com

16 May 2003

Mr. Michael Hinton, P.E.
Environmental Engineer II
New York State Department of Environmental Conservation
Division of Environmental Remediation
Region 9
270 Michigan Avenue
Buffalo, New York 14203-2999

RE: Treatment System Design Modifications Associated with the Ground-Water Treatment System at the Airco Parcel, Niagara Falls, New York
EA Project No. 12040.83

Dear Mr. Hinton:

As discussed during our recent conversations, some changes were implemented to the layout of the treatment system proposed in our 15 April 2003 design submittal. As noted, the existing design was proving to be more costly to implement than originally forecasted, which required modifications to the process flow to keep the construction costs within the original budget. Prior to the changes being implemented, EA was predicting a cost overrun of approximately $250,000, primarily due to the use of the pre-cast concrete tanks, which were not readily adaptable to the design and, subsequently, were driving the costs up considerably.

Attached please find 3 copies of revised Drawings G-2 and G-3. The drawings depict the required changes to the system to limit costs, while maintaining the appropriate treatment processes. The following text describes the new treatment system layout, and the changes that have been incorporated:

- The Influent Wetwell Pump Station will now be a pre-fabricated fiberglass pump station. The controls will be the same, but the control panel has been eliminated. Appropriate manual controls, disconnects, and electrical junction boxes have been added to allow for lock-out/tag-out procedures for maintenance. The control located at the main treatment area will monitor the water level in the pump station, and activate the pumps accordingly.

- The carbon dioxide aeration chamber will be made of fiberglass. No other changes are noted.

- The settling tank has been removed and replaced with a lined sedimentation pond, 40-mil HDPE liner, of greater capacity. It will remain the primary settling point for hardness precipitated after pH adjustment has occurred.

- The Sedimentation Pond Dual pump station drywell has been added. It is made of fiberglass, and will contain 2 pumps. The first pump will pump water through the ZVI tank; the second will pump water from the second sedimentation pond into the shallow wetland.

- The ZVI tank will be made of HDPE instead of concrete. No other changes were noted.

- A second sedimentation pond, of equal capacity to the first, has been added to replace the deep sedimentation wetland. The sedimentation pond is smaller than the original proposed wetland, but maintains enough capacity to provide the required retention time of 10-12 hours, even during a 100-year return frequency storm event.

- The shallow wetland remains relatively unchanged. The point at which water enters the wetland was relocated after removal of the deep wetland, and some minor grading was changed within the wetland to channel flow accordingly.

- The effluent drywell pump station will be made of fiberglass. No other changes were noted.

Currently, EA is in the process of procuring the necessary materials and equipment to meet the 2 June 2003 deadline for mobilization. EA would appreciate as prompt a response as possible from the New York State Department of Environmental Conservation so that EA can receive the permit to construct the carbon dioxide storage tank pad and installation.

Should you have any questions or comments regarding the materials provided herein, please do not hesitate to contact me at (845) 565-8100.

Respectfully,

EA ENGINEERING, P.C.

Charles E. McLeod, Jr., P.E.
Vice President

CEM/caw
Attachments

cc: M. Resh (BOC)
M. Graham (Phillips Lytle)
S. Rival (EA)
F. Clark (Town of Niagara)
M. Forcucci (NYSDOH)

Attachment

Revised Drawings

CONTENTS

Page

LIST OF FIGURES

1. INTRODUCTION

EA Engineering, P.C. and its affiliate EA Science and Technology prepared this design/build Work Plan for The BOC Group. The primary objective of the Work Plan is to design and construct the remedial alternative selected for addressing ground water, which currently recharges to surface water in the southwest corner of the Airco parcel in Niagara Falls, New York (the Project) (Figures 1 and 2). This Work Plan builds upon the findings of the pre-design investigation, closure plan, Interim Remedial Measure Program, post-closure operations and facility maintenance and the Feasibility Study (FS) that have been conducted since August 1999. The remedial actions described in this document are being performed under the existing Order on Consent No. B9-0470-94-12, which will be amended, as required, for completion of remedial actions.

1.1 DESIGN-BUILD WORK PLAN OBJECTIVES

1.1.1 Purpose

The purpose of the Work Plan is to outline the design elements of the treatment system, which will be consistent with the remedial alternatives for the Project area as depicted in the FS. This Work Plan also outlines details of construction, and provides a schedule to complete this additional remedial action.

1.1.2 Scope

The Work Plan was developed based upon the FS prepared to address ground water, which currently recharges to surface water in the Project area. During construction of the capping system in 2000, a relief pipe system to allow ground water to continue to recharge to the surface in the Project area was installed to allow perched water to exit from under the cap without causing slope instability. It was initially believed that post-capping, the discharge would eventually dissipate. The discharge has continued in the Project area, and this Work Plan has been developed to present the design and implementation of the remedial action that will be implemented to address that concern. The design presented in the following sections details a system that is capable of addressing the constituents of concern at concentrations consistent with the data collected during the long-term monitoring program. It is anticipated that specific discharge limits for the constituents of concern will be set by the New York State Department of Environmental Conservation (NYSDEC) and that a State Pollutant Discharge Elimination System permit will not be required since the remediation is occurring under an existing Order on Consent.

1.1.3 Report Organization

This report is divided into the following chapters:

- **Section 1, Introduction**—Outlines the purpose and scope of the Work Plan.
- **Section 2, Project Team**—Provides an overview of the project team members, and describes their area of responsibilities.
- **Section 3, Treatment System Design**—Presents an overview of the treatment system process flow and components.
- **Section 4, Treatment System Construction**—Presents an overview of the treatment system construction sequencing, means, and methods to implement the design.
- **Section 5, Project Schedule**—Provides a design and construction schedule detailing the necessary elements to be accomplished to complete the remedial actions within the Project area.
- **Appendix A**—Bench-scale study results
- **Appendix B**—Design drawing set.

1.2 U.S. VANADIUM CORPORATION OF AMERICA SITE DESCRIPTION AND BOUNDARIES

The Vanadium Corporation of America site in Niagara Falls, New York (Figure 3) is currently listed as a Class 2 site in the New York State Registry of Inactive Hazardous Waste Sites (Site No. 932001). This classification indicates that NYSDEC considers the Vanadium Corporation of America site to be a significant threat to public health or the environment, and requires remedial action. The Vanadium Corporation of America site consists of three separate properties:

- A 25-acre Airco parcel owned by Airco Properties, Inc.
- A 37-acre parcel owned by SKW Metals and Alloys, Inc.
- A 53-acre parcel owned by Niagara Mohawk Power Corporation/New York Power Authority.

The Airco parcel is the middle of three parcels that comprise the Vanadium Corporation of America site. The Airco parcel was owned and used by the Vanadium Corporation of America from 1920 to 1964 for disposal of the following materials: stainless steel (lime) slag, ferromanganese slag, ferrochrome silicon slag and dust, and ferrosilicon dust. It is estimated that during the 44 years of operation by Vanadium Corporation of America, 600,000 tons of slag and dust and 90,000 tons of wood, brick, and ash refuse were dumped throughout the Airco parcel and adjacent SKW and Niagara Mohawk Power Corporation/New York Power Authority subsites. A full description of the background, site use, and physical conditions of the site can be found in the Feasibility Study (EA 2003[1]).

1.3 INTERIM REMEDIAL MEASURE PROGRAM

As part of the Interim Remedial Measure Program, BOC entered into Order on Consent No. B9-0470-94-12 on 17 May 2000. The terms of this Order constitute the complete and entire Order concerning the implementation of an interim remedial measure for the Airco property and demonstrates conformance with all applicable requirements of Title 6 of the New York Codes, Rules, and Regulations (NYCRR) Part 375, Environmental Conservation Law Article 27, Title 7, and 6 NYCRR Part 360 requirements pertaining to permitting, closure, and post-closure care of the landfill, and all other state plans, standards, or regulations that relate to the Interim Remedial Measure Program.

Remedial measures associated with the cap installation were completed at the Airco parcel during 2000, which included installation of a low permeability cap and ground-water relief system. EA has been performing long-term monitoring and engineering inspections on a quarterly basis since the closure, in accordance with the Post-Closure Monitoring and Facility Maintenance Plan. Overall, the cap system is performing as expected.

The Interim Remedial Measure Program was implemented to effect the closure of the landfill and to address the elevated pH leachate daylighting at various locations. In 2000, the landfill was capped, but the elevated pH leachate has continued to daylight in the Project area. Flow monitoring and quarterly sampling were initiated as part of post-closure operations and facility maintenance. The data collected since December 2000 indicated that the leachate was actually shallow ground-water recharging to surface water. The data also indicated that the recharge of ground water at the Project area would continue to flow seasonally. The data further indicated that elevated Cr(VI) concentrations and pH in ground water, upon mixing with surface water, remained in excess of the ambient water quality criteria. Therefore, this Work Plan has been developed to implement additional remedial actions, which have been deemed necessary to meet the goals of the interim remedial measures program.

1. EA Engineering, P.C. and its Affiliate EA Science and Technology. 2003. Final Focused Ground-Water Feasibility Study for the Airco Parcel, Niagara Falls, New York. March.

2. PROJECT TEAM

This chapter presents EA's design-build project team and discusses the roles and responsibilities of each team member.

EA has assembled a project team to provide design-build services for remedial actions to be implemented to address ground water recharging to surface in the Project area at the Airco parcel. The team offers the full range of technical skills and experience necessary to successfully complete the project. Figure 4 illustrates EA's organizational structure for completing the design activities.

2.1 EA PROJECT TEAM

The following summaries provide a brief description of the experience of the key EA project personnel who will be assigned to the project.

Mr. Charles E. McLeod, Jr., P.E., will serve as *Project Manager*. His responsibilities will include the following:

- Coordinating EA personnel to ensure successful completion of the design activities
- Attending and leading design meetings
- Managing project finances in compliance with established project budgets.

Mr. McLeod is a New York State-registered Professional Engineer who manages and leads design efforts for environmental engineering projects. He is a civil engineer with 13 years of experience involving management and administration of a variety of solid waste and environmental projects, including development of design drawings and specifications, construction project management, and post-closure monitoring.

Mr. McLeod will also serve as co-field superintendent during implementation of the design. During field activities, Mr. McLeod will be responsible for the following:

- Coordinating EA personnel and subcontractors to ensure successful implementation of the design activities
- Attending and leading progress meetings with NYSDEC personnel
- Enforcing the site-specific health and safety plan
- Field calibrating the air monitoring equipment
- Performing air monitoring as outlined in the site-specific health and safety plan

- Managing project finances in compliance with established project budgets

- Performing start-up and prove-out testing to determine that the system is operational and functioning as designed.

Mr. David Santoro, P.E., L.S., will serve as the *Quality Assurance/Quality Control Officer and Chief Engineer* for this project. Mr. Santoro is President of EA Engineering, P.C., and Chief Engineer and Director of Quality Control for engineering. Resulting from his more than 38 years of experience, he has become an authority on the design and management of solid and hazardous waste management facilities and site closures. He is particularly experienced in the use of liners in the design and construction of such facilities, as well as the management, certification, and permitting of construction activities for industrial and federal projects. Through such experience, he has developed a thorough understanding of chemical fate and transport and hydrogeology.

Mr. Santoro is a Senior Professional Engineer registered in New York State and is responsible for ensuring the professional quality of design. Mr. Santoro supervises professional engineering design, the preparation of contract specifications, and construction management and inspections; assists with public interaction/acceptance programs; and has provided expert testimony.
Mr. Santoro has also directed the design and construction of sanitary and secure landfills and landfill closures utilizing synthetic membranes in seven states, including New York.

Mr. Santoro's responsibilities will include the following:

- Oversight of technical development
- Final review and approval of work products
- Engineer-of-Record, sealing of drawings
- Maintenance of project team integrity.

Mr. Steve Rival, will serve as *Design Manager*. His responsibilities will include the following:

- Management of the design team
- Oversight of the preparation of design documents.

Mr. Rival has a degree in chemical engineering technology and more than 25 years of experience in hazardous waste remediation design and construction.

Mr. Rival will also serve as co-field superintendent during implementation of the design. During field activities, Mr. Rival will be responsible for the following:

- Coordinating EA personnel and subcontractors during construction

- Attending and leading progress meetings with NYSDEC personnel

- Enforcing the site-specific safety and health plan

- Performing startup and proveout testing to determine that the system is operational and functioning as designed.

Ms. Sarah Ridgway, P.E., will serve as the *Project Engineer*. Her responsibilities will include the following:

- Leading the design effort
- Preparing the design documents.

Ms. Ridgway is a registered Professional Engineer with 8 years of experience in environmental projects, including leachate treatment design, and soil and ground-water remediation.

Mr. Paul Muessig will serve as the *Project Scientist*. His responsibilities will include the following:

- Preparing the wetland construction plan included in the design drawing set
- Overseeing the purchase and installation of wetland flora
- Re-inspection of the wetland area in the Fall of 2003.

Mr. Muessig has over 28 years of experience as an environmental scientist. Mr. Muessig has been involved with the wetland encroachment and waste excavation during previous remedial activities at the site, and performed the assessment of the wetlands in conjunction with preparation of the Feasibility Study.

Mr. Scott Graham will serve as the *Project Hydrogeologist*. His responsibilities will include the following:

- Preparing and submitting a revised post-closure monitoring and maintenance plan in accordance with Title 6, Part 360 of the New York State Codes, Rules, and Regulations (NYCRR).

Mr. Graham is experienced with 6 NYCRR Part 360 regulations and the development and implementation of the post-closure monitoring and maintenance plans. Since 2000, Mr. Graham has been involved with implementation of the long-term monitoring program at the Airco parcel.

Mr. Kris Hoiem, CIH, will serve as the *Manager of Health and Safety*. His responsibilities will include the following:

- Reviewing the site-specific health and safety plan prior to construction-related activities to assess if changes to the plan are required to address any new health and safety concerns

- Monitoring site activities through routine contact with the Site Health and Safety Officer.

Mr. Hoiem is a Certified Industrial hygienist, with over 30 years of environmental health and safety and industrial hygiene experience.

2.2 KEY REMEDIAL ACTION SUBCONTRACTORS

The following sections provide a brief description of the experience of key remedial action subcontractors to be involved with implementation of the remedial action.

2.2.1 Treatment System Construction

To maintain continuity, and reduce the possibility of damage to the cap, the same contractor, SLC Environmental Services, Inc. located in Lockport, New York, will be retained to perform the excavation and installation of the treatment system. Primary responsibilities will include installation of the wetwell, below grade piping and electrical conduits, carbon dioxide aeration chamber, settling tank, zero valence iron (ZVI) reactive media vessel, and construction of the wetlands. To minimize cost, EA will purchase the process tanks, and will coordinate with SLC to utilize local reputable vendors and suppliers directly.

2.2.2 Control and Electrical System Integration

EA has selected Miller Environmental Service, Inc. (MES) to provide system integration and startup. MES is located in Hampstead, Maryland and has a long-standing relationship with EA, providing the highest quality products and workmanship. The decision to utilize MES versus local craft labor was made based on the complexity of the process controls. Local craft labor will be utilized to install the electrical meter services, as required by the local utility. As noted above, the treatment electrical conduits and direct bury electrical and control wire will be performed by SLC with EA assistance; MES will not be involved during installation of the major treatment system components. MES will be performing most of its work elements in Hampstead, Maryland during construction of the two control panels. MES will be onsite to complete the control system installation, and during startup and proveout.

2.2.3 Subconsultant Professional Services

Other subconsultants and professional services include surveying, geotechnical, and analytical laboratories. For these services, EA will utilize Wendel-Duchscherer, Lockport, New York, for professional land surveying; Advance Testing, Inc., Campbell Hall, New York, for geotechnical services; and Environmental Laboratory Services, Syracuse, New York, for analysis of various media (water, soil, and waste).

3. TREATMENT SYSTEM DESIGN

The design addresses the collection, conveyance, treatment, and discharge of water. The design features are discussed in this section.

3.1 BASIS OF CONCEPTUAL DESIGN

The original conceptual design was outlined in an attempt to treat the water recharging to surface at the Project area. After careful evaluation during the FS process, it was determined that the conceptual design was impractical, and required some modifications. Bench-scale studies were performed throughout the FS stage and into the early stages of design to develop the required data to support the basis of design. The results of the various bench-scale studies are included in Appendix A. The design drawing set is included as Appendix B.

3.2 TREATMENT SYSTEM PROCESS FLOW

To address the high pH (>13), and the elevated Cr^{6+} concentrations, a ground water collection and treatment system has been conceived. The general process flow will include collection of untreated water in the Project area via the existing relief pipe system, conveyance of this water from the Project area via a wetwell pump station and 3-in. discharge line, pH adjustment via CO_2 aeration, primary settling, Cr^{6+} treatment through contact reaction with ZVI, final settling and buffering in a multiple stage engineered wetland, and discharge back to the Project area via a 2-in. discharged line which outlets into the offsite wetland area. The following sections will detail each of these components, including design approach and process descriptions.

3.2.1 Collection and Conveyance System

Construction of the landfill cap was completed as part of the Interim Remedial Measure program in October 2000. During construction, it was determined that a ground water relief pipe was required to allow pressure under the cap from perched water to vent to the atmosphere to prevent damage to the cap system. It was later determined that the water was not perched ground water, but the overburden ground water, and discharge from the pipe would not dissipate over time. Therefore, the existing 4-in. collection pipe has been incorporated into the design. Water will be collected and conveyed through the existing 400-ft long 4-in. diameter pipe to a concrete wetwell pump station. The wetwell will be lined with a spray-on application of corrosion-resistant material to prevent corrosion from impacting the integrity of the concrete vault. The wetwell will contain a pump that will be installed on rails to facilitate maintenance. The pump controls will be set to pump a 300-gal batch volume of water up to the CO_2 reaction chamber. The 4-in. relief pipe will enter the vault, and a new manual flow control valve, and a pneumatic shutoff valve installed. The manual ball valve will allow the operator to manually adjust the rate at which water enters the vault. A pressure transducer location in a piezometer outside the vault will record and display the static ground water elevation. The system will be operated to maintain drawdown below the cap to prevent damage to the cap system. The pneumatic shutoff valve installed in the 4-in. relief pipe entering the vault will be a normally closed ball valve. During normal operations, the valve will remain open via a portable air tank supplied pressure. During a power outage, or alarm condition, which warrants treatment system shutdown, a 3-way solenoid valve will switch position and depressurize the valve, causing it to close. This will prevent an overflow condition and uncontrolled release into the environment. Alarm conditions will be responded to within 3 hours during normal business hours, and within 12 hours during evening and weekend hours. During an alarm condition, which causes the valve to close, ground water will be stored within the waste below the cap, and within the overburden aquifer. A 12-hour period, to allow for personnel to respond, is not sufficient time to cause a release of untreated water to the environment.

3.2.2 Ground-Water pH Adjustment

The water observed discharging from the relief pipe has a pH in excess of 11, and has been observed as high as 13. To reduce the pH, the treatment process will utilize CO_2 aeration. As noted in Appendix A, bench-scale studies performed as part of the FS process indicated a high degree of success in neutralizing the water to a pH of 6.5 within 10-12 minutes. The process generated carbonic acid, which reacts to neutralize the water. A pH adjustment tank will be constructed similar to the wetwell, concrete lined with a spray-on application of corrosion-resistant material. The tank will have a conical bottom, and a motor-actuated valve on the tank effluent to facilitate emptying the tank once neutralization has occurred. A pH probe will be installed in the effluent discharge line connecting the aeration chamber to the primary settling tank to monitor pH. If the observed pH is not within the desired range of 6.0–8.0, then the programmable logical controller will increase, or decrease, the aeration time on the next batch incrementally to maintain the pH within the desired range. The settling tank will be sufficiently sized such that if a batch enters the settling tank at a slightly higher than desired pH, the volume of water per batch, as compared to the volume of water in the settling tank, will not result in a pH value in excess of the allowable range due to dilution within the settling tank.

3.2.3 Primary Settling

As noted in the bench-scale studies in Appendix A, and as observed at the Project area, the water exhibits a high hardness value, which results in the formation of a white calcium carbonate precipitate upon pH reduction. This white precipitate is not aesthetically desirable and is one of the design considerations. A settling tank has been incorporated into the design to precipitate out the precipitate prior to reaction with ZVI for hexavalent chromium reduction. The settling tank is constructed of similar materials to the wetwell and aeration chamber, concrete with polyethylene lining. The settling tank will have a minimum working volume of 15,000 gal and has a designed retention time ranging from 6 hours to 18 hours based on a maximum flow rate of 15 gpm. The tank is designed to maintain the minimum retention time of 6 hours, while allowing for the calculated production of 10,000 gal of precipitate, annually.

3.2.4 Hexavalent Chromium Reduction

The reduction of hexavalent chromium will occur within a vessel containing ZVI. The iron acts as an electron donor during the oxidation-reduction process. The hexavalent chromium will accept 3 electrons during the process to convert to trivalent chromium, and ultimately precipitate out as an insoluble compound (Appendix A). The ZVI vessel is configured to allow the required contact time at the maximum flow rate of 15 gpm. The vessel, a compartmental tank with a minimum ZVI working volume of 480 ft^3, has been designed with partition walls to reduce the potential for short-circuiting through the vessel by inclusion of horizontal channels. The vessel will also contain multiple piezometers, which can be used to check the hexavalent chromium concentrations within the vessel at various stages. This will allow the operator to track breakthrough of the ZVI and calculate when ZVI replacement will be required. The ZVI tank will also contain a clearwell at the end of the tank to accommodate filtration, if required. Based on the bench-scale studies, and proper selection of the ZVI source material, additional filtration is not warranted given the settling capacity of the engineered wetland downstream of the ZVI process.

3.2.5 Multiple Stage Engineered Wetland

The final treatment step includes processing the water through a 2-stage engineered wetland. The primary stage is deeper and larger in capacity to promote final settling of any precipitates and iron flocculent generated during the physical treatment processes. The primary stage has a volume capacity of approximately 42,400 gal at a water surface area of 2,676 ft^2. This stage will be vegetated with submergent and emergent wetland vegetation. The second stage is larger, approximately 4,019 ft^2. The water depth will, in this wetland, vary based on pump cycles to convey the treated water from the secondary wetland to the Project area for release into the environment. The volume within the secondary wetland will range from a low of 23,162.5 gal to approximately 46,325 gal. The primary and secondary wetlands are designed with a total retention time of between approximately 3 and 4 days, while maintaining sufficient capacity to control the 24-hour duration, 100-year return frequency storm event.

3.2.6 Treated Ground-Water Discharge Conveyance System

The treated water exiting the engineered wetland will be conveyed, by pumping, back to the Project area via a 2-in. discharge line. The 2-in. line, also constructed of high-density polyethylene, will be installed in the same trench as the untreated influent line from the wetwell to the aeration chamber. Both lines will be installed to a depth not less than 42 in. below ground surface, unless waste material is encountered. If the lines must be installed to a shallower depth, appropriate precautions will be employed to prevent freezing.

3.3 STORMWATER MANAGEMENT AND EROSION AND SEDIMENT CONTROLS

Stormwater is managed at the site in accordance with 6 NYCRR Part 360, Subpart 2.15(k)(2) via the existing perimeter drainage system which was designed as part of the landfill closure, and is designed to convey the peak discharge from the 24-hour duration, 25-year return frequency storm. The original conceptual design included the use of the existing swales to convey water from the northwest corner back down to the southwest corner to exit the site. An evaluation of this approach poses more concerns with regards to capacity, and winter operations.

Therefore, as noted in Section 3.2.6, the treated water will be conveyed back to the Project area via a 2-in. discharge line. The treated water will be discharged from the subsurface through a column of stone to simulate ground water naturally recharging to surface and eliminate the need for rip-rap outfalls or other erosion control devices.

It is estimated that less than one acre will be disturbed during construction of the ground water collection and treatment system. Therefore, no specific stormwater permit will be required for these remedial actions. However, best management practices will be employed to prevent the migration of sediments from disturbed areas during construction. As noted on the drawing set provided in Appendix B, EA has incorporated silt fence and straw bales, as required, to minimize the potential for overland transport of sediments during a storm event.

4. TREATMENT SYSTEM CONSTRUCTION

This Work Plan was developed to outline the details of the ground-water extraction and treatment system installed to control the release of ground water to surface water at the Project area. The design outlined in Section 3 addresses the collection, conveyance, treatment, and discharge of water. The methods and sequencing of construction for each of the design elements are discussed in this section.

4.1 TREATMENT SYSTEM COMPONENT INSTALLATION

4.1.1 Wetwell and Discharge Piping

As noted in the previous section, the existing 4-in. perforated high density polyethylene collection line will be connected to the new wetwell pump station. In order to facilitate installation of the pipeline, the overburden barrier protection and impermeable clay layers will be excavated and stockpiled adjacent to the excavation for use as common borrow backfill. Excavated waste, and soil in contact with waste, with be stockpiled on polyethylene sheeting and covered prior to sampling for disposal. After the wetwell has been installed, the excavation will be backfilled with materials that meet the requirements stipulated in the Closure Plan (EA 20002). A bypass relief pipe will be in stalled to allow the ground water to continue to recharge to surface until the treatment system is operational. Once system installation is complete, the bypass will be removed from service.

The 3-in. high density polyethylene discharge line will be installed in a trench connecting the wetwell to the carbon dioxide aeration vault. The trench will be excavated to a depth of approximately 42 in. below ground surface, or to the top of waste, whichever is shallower. The overburden clay will be re-used to backfill the trench. The excavated low permeability clay will reconditioned, as required, to facilitate installation in accordance with the specifications in the Closure Plan (EA 2000). The material will be compacted and two shelby tubes collected and tested for compliance. *In situ* density and moisture testing will be performed at a rate of four tests per lift. The trench excavation will be restored to existing conditions including a 6-in. topsoil layer and seed.

4.1.2 Carbon Dioxide Aeration Tank

The carbon dioxide aeration tank will be installed as shown on the design drawings at the existing grade. The tank will be installed at the existing grade to provide for the proper hydraulics without requiring the use of a pump to evacuate the aeration tank after pH adjustment has been completed. Prior to tank installation, the topsoil will be stripped and stockpiled for re-use and a 6-to 12-in. layer of aggregate installed to provide proper tank support. The tank will

---

2. EA Engineering, P.C. and its Affiliate EA Science and Technology. 2000. Closure Plan for the Witmer Road Landfill, Niagara Falls, New York. April.

be bermed to aesthetic reasons and to provide frost protection. Native soils excavated to facilitate installation of the primary settling tank (discussed below) will be used to berm around the tank. Topsoil and seeding will complete the installation.

4.1.3 Primary Settling Tank

The primary settling tank will require excavation into the native soils within the northwest corner of the site. The northwest corner of the site is a clean closure with no waste present. The excavated material will be used to provide frost protection of the aeration tank, and as common borrow fill around the engineered wetland discharge drywell or ZVI vault. The bottom of the excavation will be evaluated prior to placement of the tank to ensure that the subgrade is suitable for tank placement. The tank may be a modular pre-cast tank assembled onsite, or it may be cast-in-place, depending on site soil conditions.

4.1.4 Zero Valence Iron Vault

A concrete vault containing approximately 20 tons of ZVI will be installed to promote reduction of the hexavalent chromium to the less mobile and less toxic trivalent form. The ZVI vault will be installed within the edge of the engineered wetland berm to facilitate gravity flow from the tank after treatment has occurred. The vault will be installed with an additional drywell in the event that additional filtration is required prior to discharge to the engineered wetland. The need for additional filtration will be assessed during startup and proveout of the system.

4.1.5 Multiple Stage Engineered Wetland

A multiple stage wetland will be installed to promote final filtration and buffering of the treated water prior to release into the environment. The wetland will be formed using the excavated material generated from installation of the primary settling tank. This material will then be capped with either low permeable clay, or a geosynthetic clay liner. Both the low permeable clay and the geosynthetic clay liner will provide an adequate layer to prevent water from infiltrating into the subsurface in an uncontrolled manner. Prior to installation of the engineered wetland, the selected approach and materials of construction will be presented to NYSDEC personnel for approval.

The engineered wetland is designed to promote precipitation of insoluble trivalent chromium and iron. The amount of iron precipitate is directly proportional to the type of iron selected for use. Varying grades of iron exist, and higher quality iron is cleaner, and results in less insoluble precipitate. The iron selected for use, plus the configuration and size of the deep portion of the engineered wetland, will have sufficient filtering capacity to meet discharge requirements. Bench-scale study results indicate a required retention time in the deep portion of the wetland of 8-10 hours. The design currently provides a 48-hour retention time, which will allow the insoluble forms of trivalent chromium and iron to settle prior to discharge. The wetland will require periodic maintenance to remove the in insoluble precipitates, but also organic matter from decaying wetland vegetation deposited over time.

4.1.6 Treated Water Drywell Sump and Discharge Line

As part of the construction of the engineered wetland, a drywell pump station will be installed within the berm of the engineered wetland. The pump installed into the drywell will have a suction line installed into the shallow portion of the engineered wetland. This configuration will allow the pumping system to operate even if a portion of the wetland freezes due to winter weather conditions.

As noted in Section 4.1.1, a trench has been excavated to facilitate installation of the 3-in. high density polyethylene discharge line from the wetwell aeration tank, and electrical power and control wiring from the main control panel to the wetwell. In conjunction with the installation of the 3-in. line connecting the wetwell to the aeration tank, a 2-in. high density polyethylene line will be installed from the engineered wetland to the Project area to convey treated water to the Project area for discharge into the adjacent wetland.

5. PROJECT SCHEDULE

This section presents the anticipated schedule for pre-design, design, and construction activities.

5.1 PRE-DESIGN ACTIVITIES

Pre-design activities were ongoing during the preparation of the FS, and finalized prior to commencement of this Work Plan. The pre-design activities centered around various bench-scale studies to determine the appropriate materials of construction, system configuration, retention times, and process flow. Results of the various bench-scale studies are included as Appendix A and served as the basis of design for preparation of this Work Plan, and the design drawing set included as Appendix B.

5.2 DESIGN ACTIVITIES

Design activities commenced on 4 March 2003. The design documents are included as Appendix B. A technical review meeting will be scheduled with NYSDEC personnel prior to the end of April to facilitate comment review and finalization of the design. It is anticipated that completion of the Work Plan and design documents, including regulatory interaction and approval, will be completed no later than 9 May 2003.

5.3 POST-CLOSURE MONITORING AND FACILITY MAINTENANCE PLAN

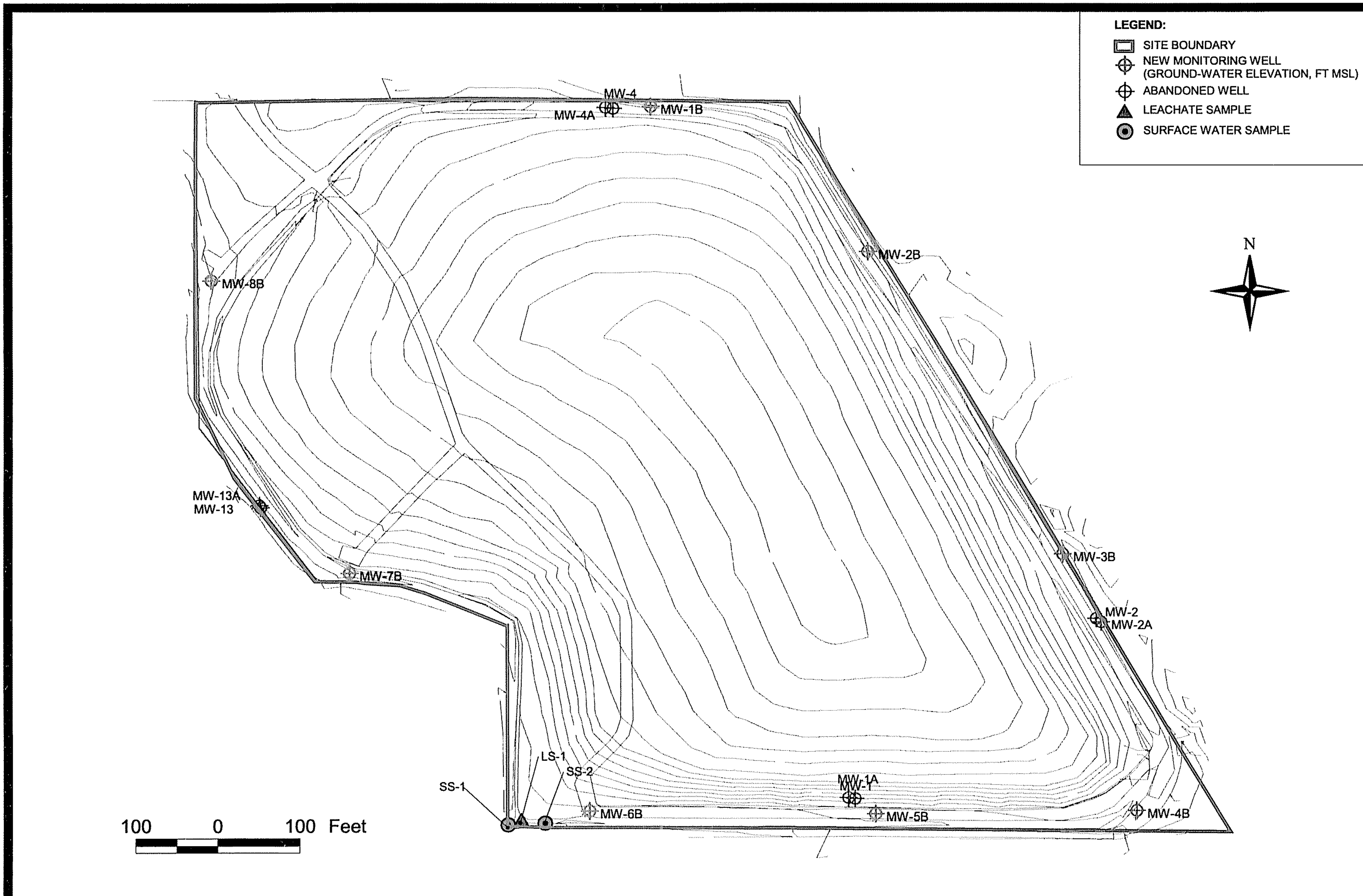
Revising the existing Post-Closure Monitoring and Facility Maintenance Plan will occur during preparation of the as-built drawings. The revised plan will also include, as an appendix, a Comprehensive Operations and Maintenance Plan to facilitate operations of the treatment system.

5.4 BID PHASE ACTIVITIES

It is anticipated that this design-build Work Plan will be submitted for NYSDEC review and approval on 11 April 2003. Procurement of subcontractors and some materials will commence within the month of April to facilitate successful implementation of the project. The remaining items will be procured at the end of April once preliminary approval has been received from NYSDEC.

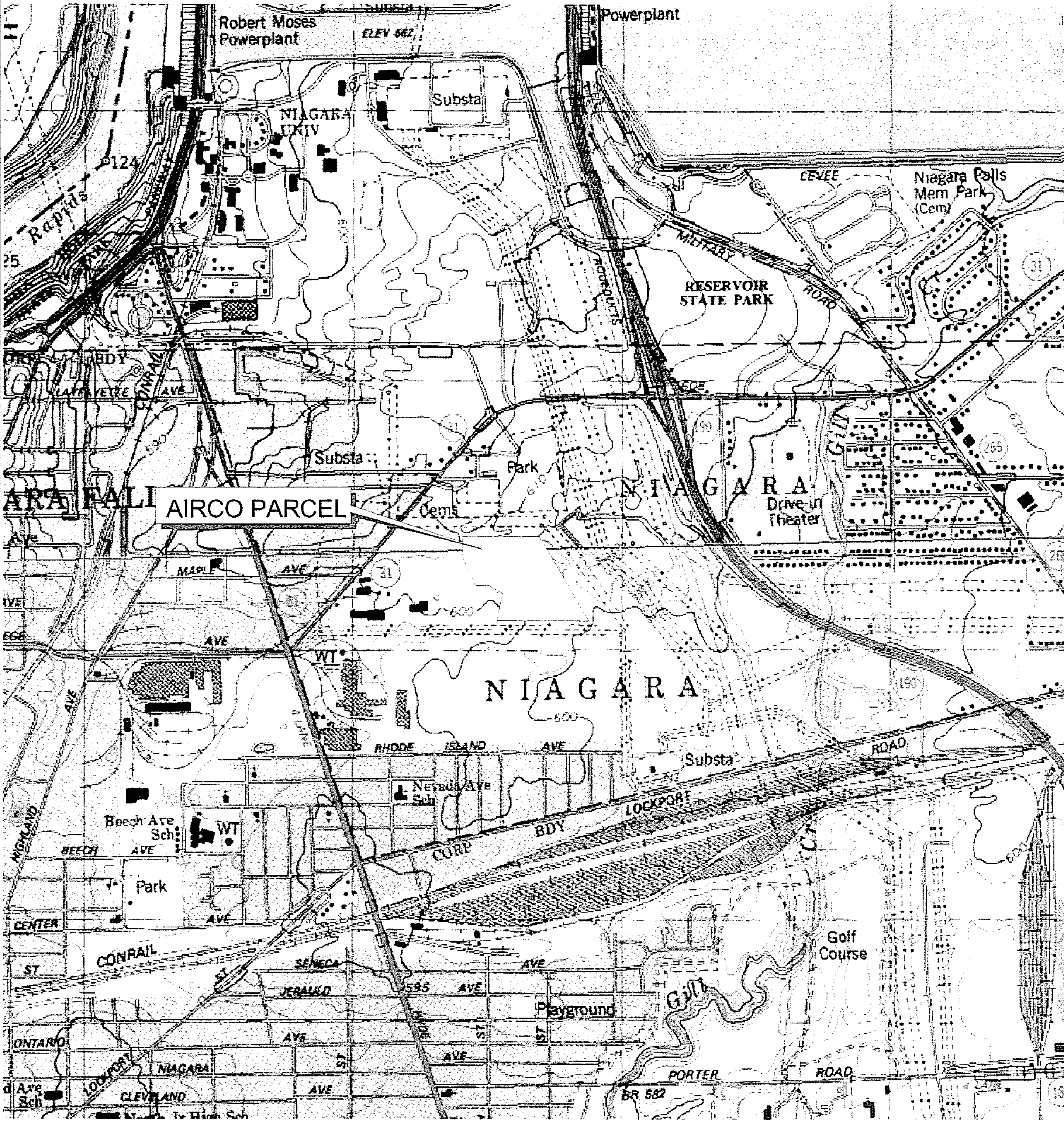
5.5 CONSTRUCTION ACTIVITIES

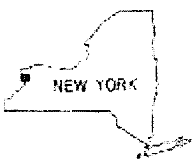
The mobilization of materials, equipment, and labor to commence construction-phase activities is anticipated to occur by 12 May 2003. Mobilization is contingent upon successful selection of qualified contractors. It is anticipated that the ground-water extraction and treatment system will be significantly complete and operational by 30 July 2003.



	AIRCO PARCEL DESIGN-BUILD WORK PLAN NIAGARA FALLS, NEW YORK	FIGURE 2 SITE PLAN

PROJECT MGR	DESIGNED BY	DRAWN BY	CHECKED BY	SCALE	DATE	PROJECT No	FILE No
CEM	DC	DC	CEM	AS SHOWN	APRIL 2003	12040.83	I:\BOC-NIAGARA-GIS\ FINAL.APR



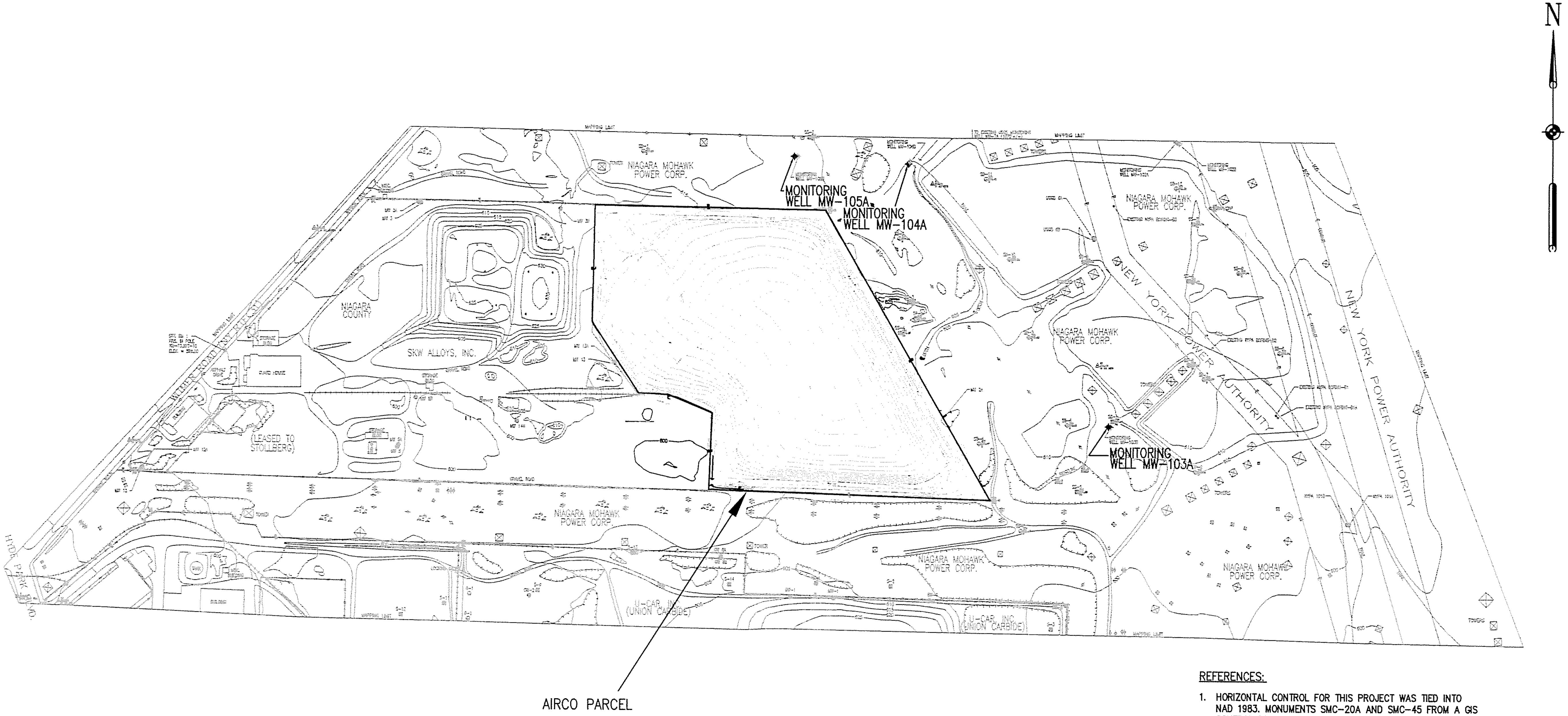


700 0 700 1400 Feet

SOURCE MAP: USGS LEWISTON AND NIAGARA FALLS 7.5 MINUTE QUADRANGLES.

	AIRCO PARCEL DESIGN-BUILD WORK PLAN NIAGARA FALLS, NEW YORK	FIGURE 1 SITE LOCATION MAP

PROJECT MGR	DESIGNED BY	DRAWN BY	CHECKED BY	SCALE	DATE	PROJECT No	FILE No
CEM	DC	DC	CEM	AS SHOWN	APRIL 2003	12040.83	I:\BOC-NIAGARA\ FINAL.APR



LEGEND

- UTILITY POLE
- PROPERTY IRON PIN
- TREE LINE
- APPROX. PROPERTY LINE
- JCL SURVEY CONTROL POINT
- x—x—x CHAIN LINK FENCE
- MONITORING WELL LOCATION

REFERENCES:

1. HORIZONTAL CONTROL FOR THIS PROJECT WAS TIED INTO NAD 1983. MONUMENTS SMC-20A AND SMC-45 FROM A GIS CONTROL PROJECT IN 1991 FOR THE CITY OF NIAGARA FALLS WAS USED.
2. VERTICAL CONTROL FOR THIS PROJECT WAS TIED INTO NGVD 1929. MONUMENT SMC-20A WITH AN ELEVATION OF 588.52 WAS USED. A SECONDARY BENCHMARK (RAILROAD SPIKE IN POLE NM-73, NYT-10) WAS SET BY LU ENGINEERS WITH AN ELEVATION OF 599.00.
3. TOPOGRAPHIC MAPPING AND 5-FT CONTOURS FOR THIS PROJECT WERE BASED ON 1"=500' PHOTOGRAPHY OBTAINED IN THE SPRING OF 1992.
4. ALL PROPERTY LINE LOCATIONS ARE APPROXIMATE. NO BOUNDARY SURVEY WAS DONE. EXISTING SURVEYS WERE UTILIZED FROM SKW ALLOYS, INC. DATED 18 FEBRUARY 1988, UNION CARBIDE LANDFILL SITE PLAN DATED 30 DECEMBER 1993, AND NEW YORK STATE POWER AUTHORITY DRAWING "NPPSKW.DWG."

400 200 0 400

GRAPHIC SCALE IN FEET

FILE: I:\BOC-NIAGARA-GIS\CAD\FIG3.DWG

EA®	AIRCO PARCEL DESIGN-BUILD WORK PLAN NIAGARA FALLS, NEW YORK	FIGURE 3 U.S. VANADIUM CORPORATION OF AMERICA SITE	DESIGNED BY DC	DRAWN BY DC	DATE APRIL 2003	PROJECT NO. 12040.83
			CHECKED BY CEM	PROJECT MGR. CEM	SCALE AS SHOWN	FIGURE 3

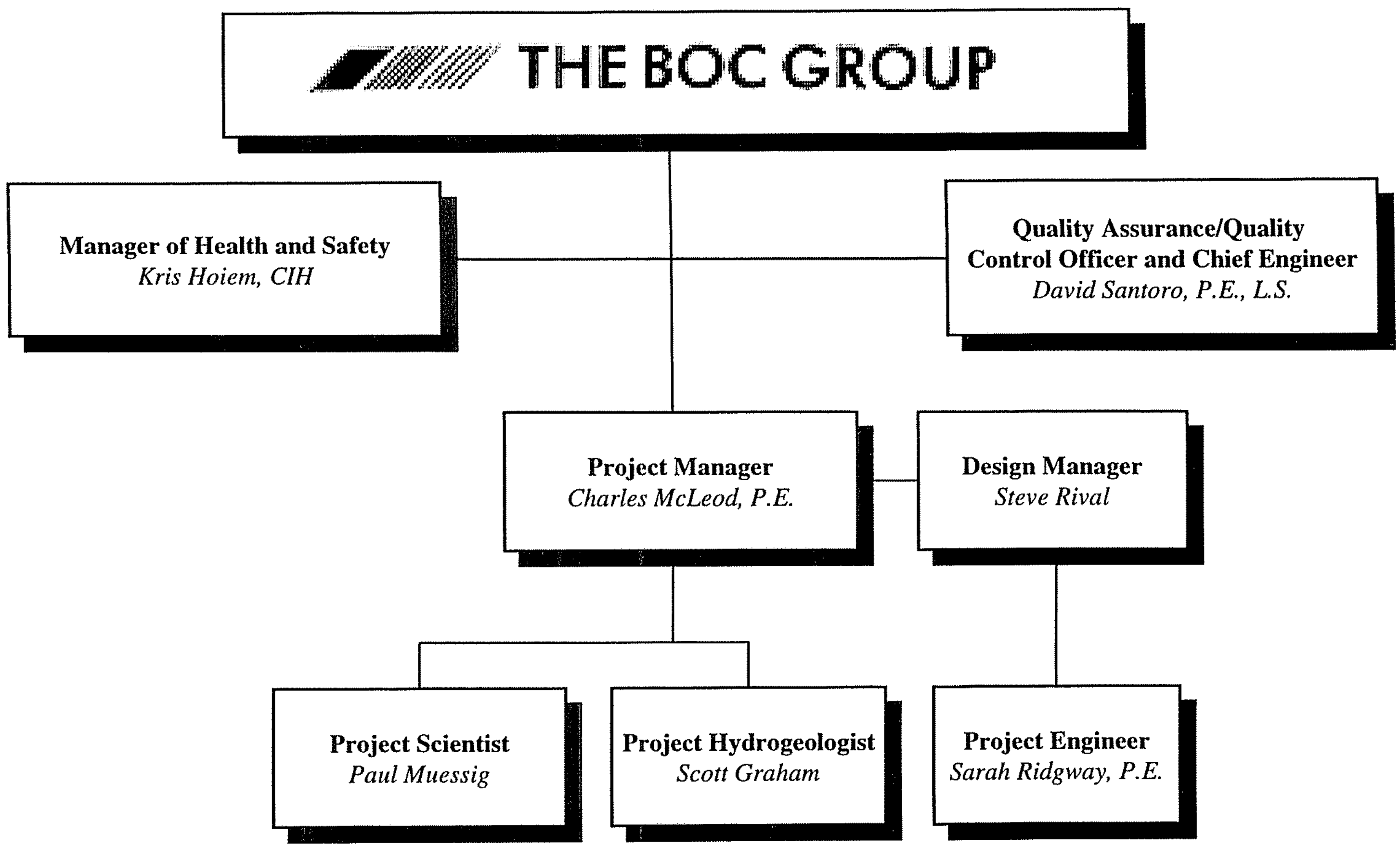


Figure 4. Project organization, Airco parcel, Niagara Falls, New York.

Appendix A

Bench-Scale Study Results

APPENDIX A

BENCH-SCALE STUDY RESULTS

A.1 INTRODUCTION

EA Engineering, P.C. and its affiliate EA Science and Technology performed bench-scale testing of potential innovative technologies in support of the preparation of the Feasibility Study. The primary objective of the bench-scale studies was to develop and evaluate potential remedial alternatives for addressing ground water, which currently recharges to surface water in the southwest corner of the Airco parcel. This report documents the results of bench-scale studies that were performed in support of Feasibility Study development and the remedial design.

A.2 BACKGROUND WATER QUALITY

Currently, ground water continues to recharge to surface water in the southwest corner of the Airco parcel. The ground water exhibits the following characteristics:

- Total chromium = approximately 400 µg/L (ranging from 75 to 100 percent as Cr^{6+})
- pH = 12.8 SU
- Eh = 68-102 millivolts
- Hardness = 1,750 mg/L as $CaCO_3$.

A.3 BENCH-SCALE TESTING GOALS

The goals of the bench-scale experiments were to determine treatment methods that would effectively neutralize the ground water to a pH between 6 and 8, and reduce the total chromium concentration to less than 100 µg/L. The system design would need to be capable of converting the hexavalent chromium to the much less toxic and less soluble trivalent chromium, and precipitating the trivalent chromium for subsequent offsite disposal.

To address these two concerns, a two-step process was conceived. Initially, the water was aerated with CO_2 gas to form carbonic acid for pH neutralization. Post-pH adjustment, the water was conveyed through a zero-valence iron (ZVI) reactive media material to facilitate reduction of the hexavalent chromium.

A.4 RESULTS OF CO_2 AERATION

Initial experiments utilized CO_2 to reduce the pH from untreated high readings to within standards (pH of 6-9 SU). It was anticipated that, in addition to obtaining the pH reduction, this would also result in the conversion of hexavalent chromium to trivalent chromium. Thermodynamically, trivalent chromium is stable at the desired pH, as long as the Eh is between 50 and 300 millivolts.

The use of CO_2 to generate carbonic acid proved effective. Figure A-1 illustrates the pH of the water sample as a function of time with aerating CO_2 at flow rates ranging from 25 to 75 mL/min for 1,000 mL of sample. Based on these experiments, it was determined that a flow rate of 50 mL CO_2/minute was effective at reducing the pH to acceptable levels after 10-12 minutes. Additional observations indicated that during the treatment, a hardness precipitate formed, ultimately settling as fine calcium carbonates ($CaCO_3$).

The volume of $CaCO_3$ produced upon pH reduction with CO_2 was experimentally determined twice. The first experiment used 4 L of discharge, from which a volume of 10 cc of $CaCO_3$ resulted. Consequently, this results in an estimate of 9.5 cc $CaCO_3$/gal of discharge. This was repeated using a discharge volume of 4.7 gal, from which 44 cc of $CaCO_3$ precipitated. This experiment resulted in a value of 9.4 cc $CaCO_3$/gal of discharge.

The redox potential of the sample increased slightly during the aeration process, but typically concluded at approximately 200 millivolts. A comparison of traditional Eh-pH diagrams showed that trivalent chromium should be in the thermodynamically stable form at this Eh and a pH of 6.2. However, analytical measurement of chromium showed that concentrations of chromium were still approximately 400 µg/L, and that the chromium was present in the more toxic and mobile hexavalent form. It appeared that the kinetics (actual process to convert from Cr^{6+} to Cr^{3+}) were more important than the most thermodynamically stable species, as predicted by a typical Eh-pH graph. For this reason, the decision was made to examine the reduction of hexavalent chromium to trivalent chromium using ZVI after pH adjustment was completed.

A.5 REDUCTION RESULTS UTILIZING WITH ZERO-VALENCE IRON

ZVI was successful at reducing the hexavalent chromium as long as the pH of the sample was less than 8.0. Initial hexavalent chromium concentrations ranged from 390 to 430 µg/L. A 200-mL sample of reduced pH (post-CO_2 aeration) was then reacted with 10 g of 8/50 sieved ZVI (Peerless). The hexavalent chromium concentrations were reduced to concentrations ranging from <5 to 17 µg/L. Additionally, the total chromium concentrations were reduced to concentrations ranging from 100 to 170 µg/L.

The following sections describe experiments designed to answer specific questions necessary for designing the treatment system.

A.5.1 Analytical Methodology for the Analysis of Total and Hexavalent Chromium

Total and hexavalent chromium concentrations were determined in-house using Hach methods. Hexavalent chromium was determined using Hach Method 8083, which used 1,5-diphenylcarbohydrazide, which reacts with the hexavalent chromium to form a purple color. Hexavalent chromium concentrations are measured spectrophotometrically at 540 nm. Total chromium was determined using Hach Method 8084. This procedure oxidizes all chromium in the sample to hexavalent chromium using the alkaline hypobromide oxidation method, followed

Cr. This time, the measurement was approximately at the detection limit of 5 µg/L (7 µg/L). The filtered sample was totally clear, and did not have a yellow color. Consequently, it can be concluded that all of the trivalent chromium after treatment was associated with particulate matter. This is not surprising because once reduced to Cr^{3+}, the chromium reacts with hydroxide ions to form $Cr(OH)_3$, which is an insoluble compound at a pH greater than 5.0.

A.5.4 Experiments Examining Aspects of the Iron Used for Reduction

- Residual Iron Post-Reduction

There were concerns that New York State criteria for iron may be exceeded in sample effluent released once the Cr^{6+} has been reduced to Cr^{3+} using Fe^0. These concerns were demonstrated by a pale yellow color of the water after such treatment. Samples were prepared by bubbling CO_2 through 2,000 mL of effluent with an initial pH of 12.6 at a flow rate of 50 mL/min for 15 minutes, at which time the pH had decreased to 8.0. Two percent (by weight) Fe^0 was added to the samples and allowed to react with Cr^{6+} for 5 minutes. Part of the sample was filtered through 0.45-µm glass fiber filters, and placed into a pre-preserved (HNO_3) sample container. An unfiltered sample was similarly placed in a pre-preserved (HNO_3) sample container. These samples were submitted for analytical determination and subsequently reported as 7,940 µg/L total iron and 1,490 µg/L dissolved iron. Additionally, it was observed that while the total samples exhibited a pale yellow color, the color was absent from the filtered samples.

The significant reduction of iron concentrations by filtration of the sample shows that most of the total iron is associated with particulate matter that is larger than 0.45 µm. It was thought that over time, the iron particulate matter would settle out. Consequently, some experiments were performed in which treated effluent was left to stand for a period of time. It was found that the majority of iron precipitated out over a period of 8-10 hours, and was completely precipitated within a matter of a few days. Once treated, it is planned that the water will be released into an onsite engineered treatment wetland with a retention time greater than that required for the iron to precipitate; consequently, additional mechanical filtration of the water should not be required.

- Investigation of Alternate Sources of Fe^0 to Optimize the Treatment System

Initial reduction experiments were conducted using Peerless 8/50 aggregate size. Because of iron carryover, it was decided to increase the aggregate size to 8/20, resulting in fewer small particles of iron. Samples of 4/20 and 8/20 aggregate size Fe^0 were obtained from Peerless and from Connelly-GMP, respectively, and tested. It was found that the Connelly-GMP product produced a cleaner discharge, and was less yellow in color. Additionally, ARS Technologies was contacted. ARS manufactures food-grade quality iron that is expensive at $1.79 per pound. Additionally, the product consists of small sphericals that range from 40 to 80 µm, and could get carried through the treatment system and also has a low porosity. For these reasons, the ARS Technologies material was not selected as appropriate to this application. The Connelly-GMP product is a good choice for this system, and all further experiments were performed using this product.

by analysis of hexavalent chromium using 1,5-diphenylcarbohydrazide as discussed above. The detection limit reported by Hach, and examined in these experiments, was found to be 5 μg/L total chromium and hexavalent chromium.

Standard Cr^{6+} and Cr^{3+} solutions were obtained from Hach. Both of these standard solutions were 50 mg/L. A 1/100 dilution was taken for both standards producing standard solutions at 500 μg/L Cr^{6+} and Cr^{3+}. These standards were then taken through the appropriate Hach method. The results are shown below:

- Nominal concentration for both Cr^{6+} and Cr^{3+} = 500 μg/L
- Measured Cr^{6+} = 515 and 523 μg/L (two separate measurements)
- Measured Cr^{3+} = 454 μg/L.

EA concluded from these preliminary tests that the Hach method is reasonably precise for Cr^{6+} (see the two separate measurements), and that the methods may slightly overestimate Cr^{6+} but slightly underestimate Cr^{3+}. Both of these measurements are reasonably accurate and suitable for the purpose of bench-scale testing.

A.5.2 The Effect of pH on Reduction Ability of Fe^0

A review of the scientific literature related to the reduction of chromium with iron indicated that such a reduction is not effective at high pH levels. This was verified using a water sample collected from the site at the original pH (12.8) and an initial Cr^{6+} concentration of 390 μg/L. A 200-mL sample was reacted with 10 g of 8/50 sieved ZVI for 5 minutes. The resultant Cr^{6+} concentration was 320 mg/L, showing inefficient reduction due to the reduction reaction that utilizes hydrogen ions to proceed:

$$3\,Fe^{2+} + HCrO_4^{+} + 7\,H^{+} \rightarrow 3\,Fe^{3+} + Cr^{3+} + 4\,H_2O$$

At a pH of 12.8, there are insufficient hydrogen ions to allow the reaction to proceed and, therefore, it was determined that pH reduction via CO_2 aeration would be required prior to ZVI treatment. Consequently, further bench-scale tests were performed after aerating the sample with CO_2 to reduce the pH.

A.5.3 State of Cr^{3+} after Reduction

After reduction, the state of CR^{3+} was assessed to determine whether it was present in the dissolved or solid form. To answer this, an effluent sample ($Cr6^{+}$ = 430 μg/L) was treated with CO_2 until the pH dropped to 7.5; 1,000 mL of this solution was treated with 2 percent (by weight) Fe^0 and allowed to react for 10 minutes. The measurement of Cr^{6+} was below the detection limit of 5 μg/L (3 μg/L). Knowing that all the hexavalent chromium had been reduced to Cr^{3+}, total Cr was measured in an unfiltered sample, resulting in a measurement of 272 μg/L Cr^{3+}. In addition, the unfiltered sample had a yellowish color, and had obvious particulate matter in it. A portion of this sample was filtered using 0.45-μm glass fiber filters, and re-run for total

- Determination of the Density of the Connelly-GMP 8/20 Fe^0

The density of the Connelly-GMP 8/20 product is listed at 110-130 lb/ft^3. The density of the product was also determined by taking 50 mL of iron, and determining the mass (85.7 g). This calculates out to be a density of 107 lb/ft^3. The product will probably also settle over time, resulting in the producer's estimated density of 110-130 lb/ft^3.

- Determination of the Porosity of Connelly-GMP 8/20 Fe^0

The porosity of Connelly-GMP 8/20 product was calculated in two ways. First, it was determined experimentally by taking a known volume of the iron (50 mL) and adding water until it was filled with water (35 mL). Consequently, the experimentally determined porosity is 70 percent. Additionally, if one uses the manufacturer's listed density of 120 g/ft^3, and the density of pure iron (450 lb/ft^3), a porosity of 73 percent is calculated. Consequently, a porosity of 70-75 percent is appropriate for this product.

A.5.5 Reduction Column and Breakthrough Experiments

- Set up a Chromium Reduction Column Apparatus

The system planned for reduction of hexavalent chromium to trivalent chromium involves flowing pH-adjusted discharge through a column or trough of Fe^0. The apparatus constructed for the laboratory is shown in Figure A-2. The reduced pH discharge (pH = 7.3, located in the container on the black cases) was pumped into the bottom of a column containing a known mass of Fe^0, and discharged to the container on the floor on Figure A-2. The pale yellow color of the discharge after this treatment is evident in the beaker shown in the figure.

- Determine the Hexavalent Chromium Reduction Capacity of the Selected Fe^0

Based on information, it had been predicted that the reduction capacity of zero-valent iron would be approximately 1.2 mg Cr^{6+}/g Fe^0. Breakthrough experiments were performed by loading the column shown on Figure A-2 with 10 g of iron, and pumping through water such that the retention time in the column was 1 minute. This experiment was performed twice, with similar results for both runs. The results of these experiments are shown on Figure A-3, which shows that breakthrough occurs with the Connelly-GMP 8/20 aggregate iron at a loading of approximately 0.7 mg Cr^{6+}/g Fe^0.

A.6 CONCLUSIONS

The use of CO_2 to generate carbonic acid was successful in reducing the pH from 12+ to acceptable levels (6-8). However, merely lowering the pH was not successful at reducing the hexavalent chromium concentrations. Reduction of hexavalent chromium to trivalent chromium was found to be successful utilizing ZVI, only after the pH had been reduced using CO_2. Based on the bench-scale results, it is expected that dissolved total chromium concentrations will be below the goal of 100 μg/L, and that the hexavalent chromium concentrations will be below

10 µg/L. The removal of chromium after treatment with ZVI is expected to occur because the chromium precipitates as an insoluble form ($Cr[OH]_3$), and is removed from the water solution via settling.

By-products are formed during the pH neutralization and hexavalent chromium reduction processes. These include a hardness and chromium precipitate and dissolved iron. The precipitation of the calcium carbonate, formed during pH reduction, occurs over a period of approximately 10 minutes. Settling this floc out will be important to maintain the aesthetic quality of treated water discharged at ground surface. Furthermore, iron concentrations in water after treatment with ZVI exceed the ground-water standards; although over a period of 8-10 hours, the iron had precipitated out. Retention time within the engineered wetland will be sufficient such that any iron will precipitate prior to release from the wetland.

The trivalent chromium resulting after the reduction step with Fe^0 is associated with particulate matter. Dissolved total chromium concentrations were below the detection limit of 10 µg/L after treatment. Even using a water hardness of 100 mg/L as $CaCO_3$ the chronic water quality criterion for trivalent chromium is 74 µg/L, resulting in the conclusion that chromium (hexavalent or trivalent) is no longer an issue. Use of the more realistic higher hardness concentration from the effluent would result in an even higher water quality criterion.

Connelly-GMP 8/20 aggregate iron was found to be the best iron for use because it is cleaner and more consistent. This iron was found to have a density of 107 lb/ft^3, similar to the manufacturer's range of 110-130 lb/ft^3. Its porosity was found to be 70-75 percent. The breakthrough of hexavalent chromium using Connelly-GMP iron was found to occur at 0.7 mg Cr^{6+}/g Fe^0. Calcium carbonate was found to precipitate out of the discharge (following pH reduction) at a rate of 9.5 cc $CaCO_3$/gal of discharge.

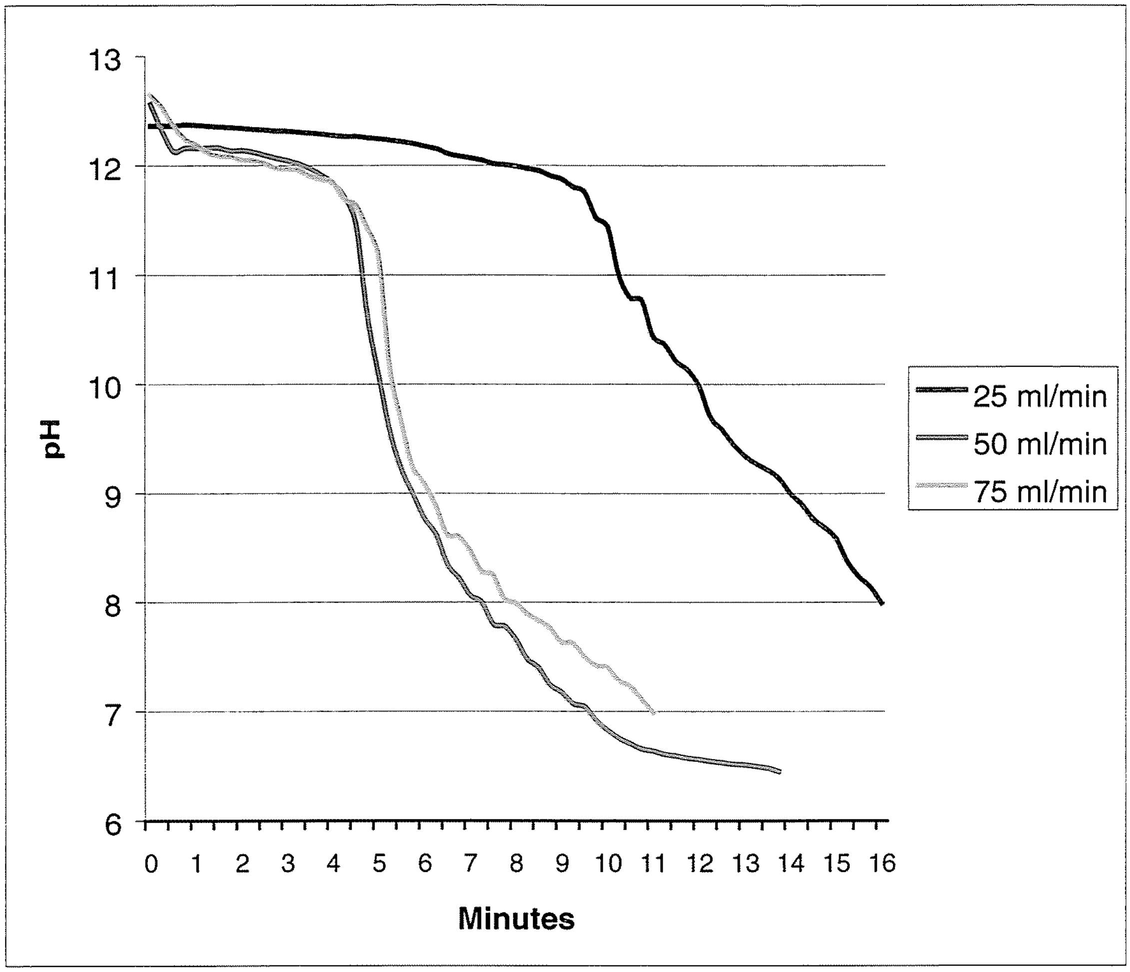


Figure A-1. Reduction in pH versus time with the addition of CO_2 gas at varying loading rates for ground water collected from the relief pipe at the Airco parcel, Niagara Falls, New York.

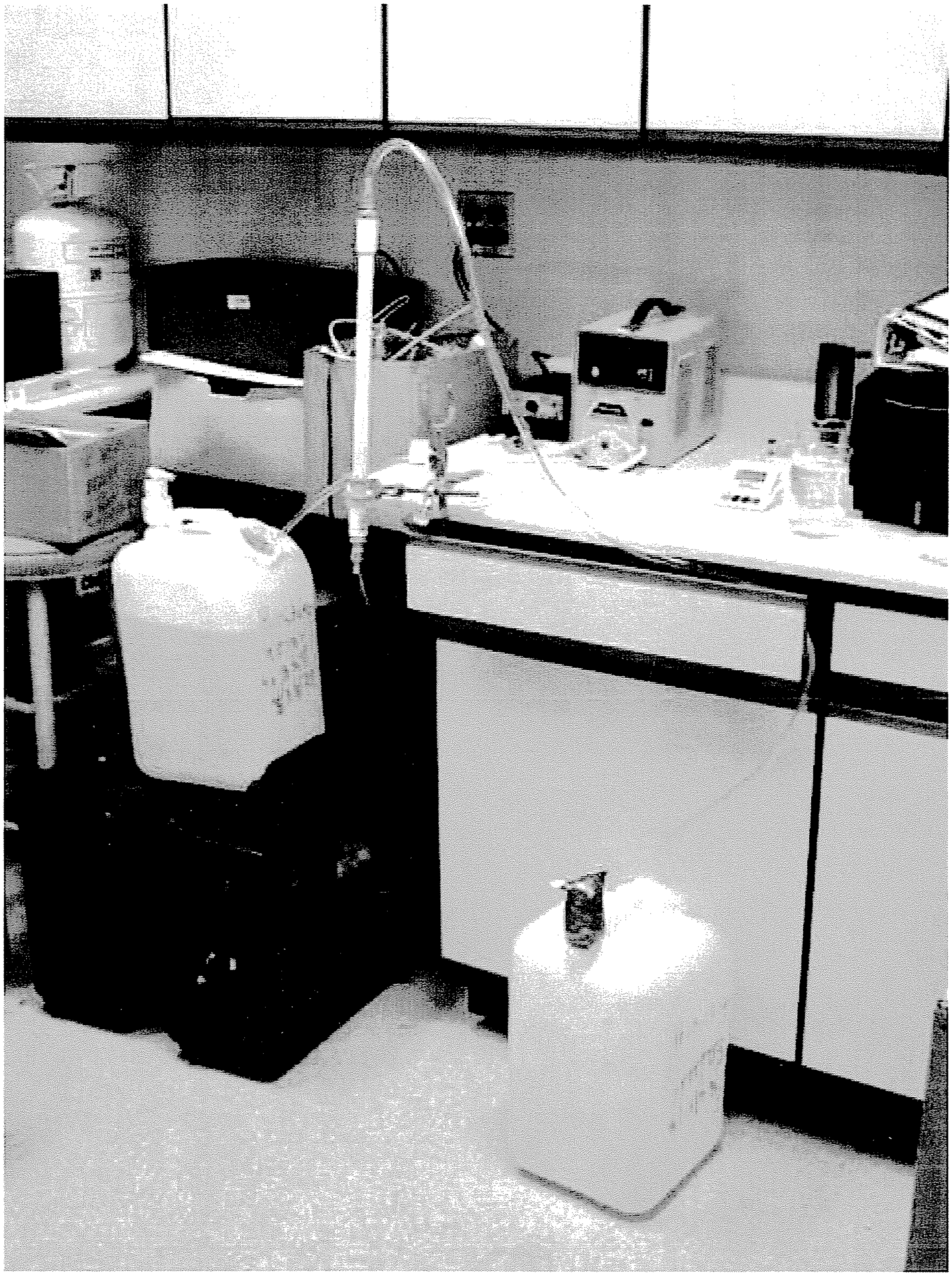


Figure A-2. Reduction column setup.

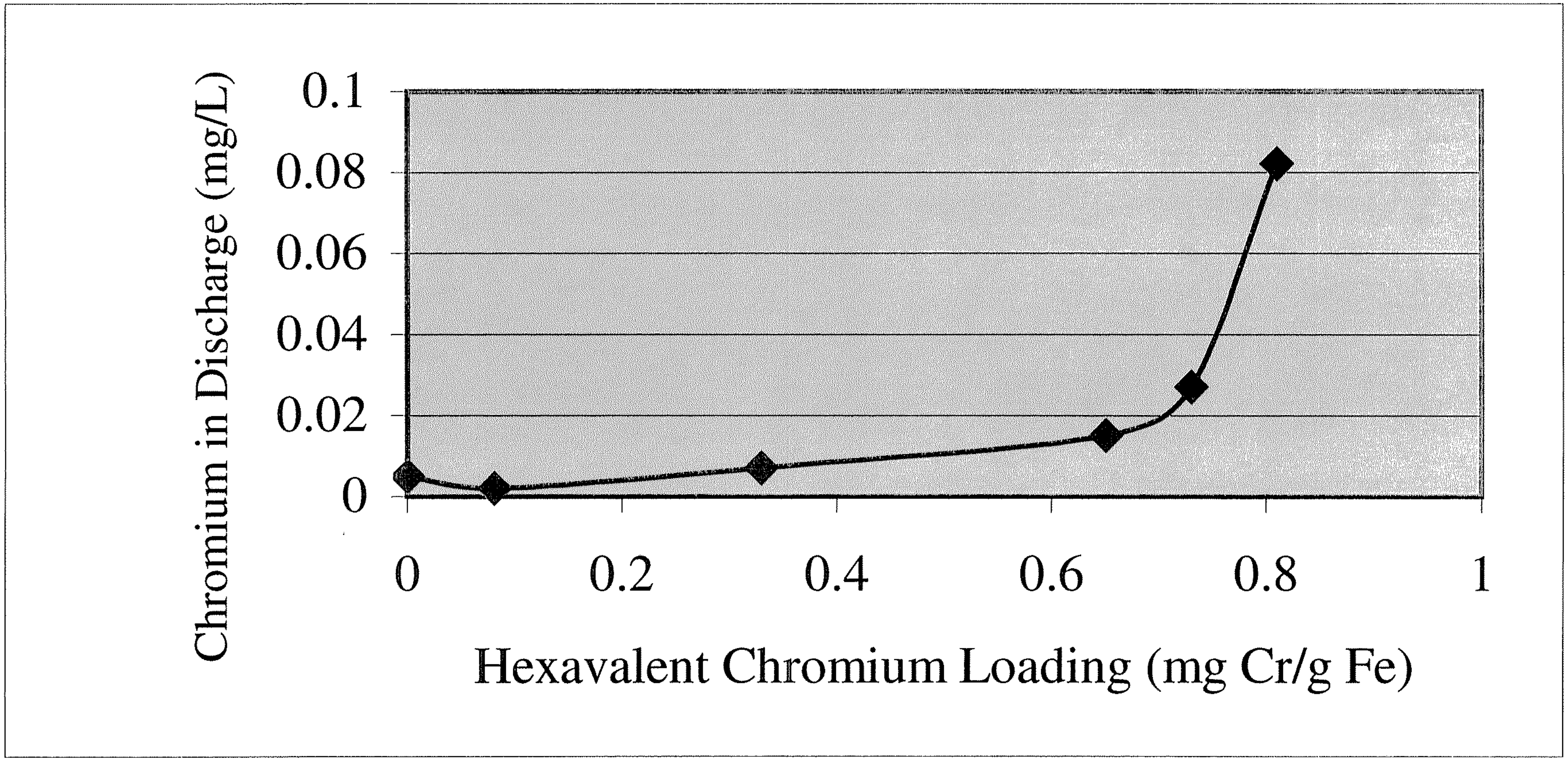


Figure A-3. Hexavalent chromium loading and breakthrough with Connelly-GMP 8/20 aggregate iron.

Appendix B

Design Drawing Set
(bound separately)